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An instrumentation grant for the purchase of an tunable diode laser-amplifier, a rf synthesizer, and a rf spectrum analyzer is used to significantly enhance current research and support new investigations in optical parametric oscillators and wide-span optical frequency comb generation. Areas of research that benefit from the new capabilities include precision frequency metrology, optical communications, and multi-wavelength information processing. The fabricated diode laser at 790 nm has been utilized to generate tunable 1.6 μm light using difference-frequency mixing in a quasi-phase matched periodically-poled lithium niobate substrate. It will also be used to pump an optical parametric oscillator for the generation of tunable 1.5–1.6 μm radiation in the mW power range. The spectrum analyzer and synthesizer are to be used for evaluating the beat-note and phase noise characteristics of optical parametric oscillators and optical frequency comb generators.

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FINAL REPORT

Diode-Pumped Optical Parametric Oscillator and Optical Frequency Comb Generation at 1.5 μm

U. S. Air Force Office of Scientific Research
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December 19, 1996

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Contents

1 Statement of Work

An instrumentation grant for the purchase of an tunable diode laser-amplifier, a rf synthesizer, and a rf spectrum analyzer is used to significantly enhance current research and support new investigations in optical parametric oscillators and wide-span optical frequency comb generation. Areas of research that benefit from the new capabilities include precision frequency metrology, optical communications, and multi-wavelength information processing. The fabricated diode laser at 790 nm has been utilized to generate tunable 1.6 μm light using difference-frequency mixing in a quasi-phase matched periodically-poled lithium niobate substrate. It will also be used to pump an optical parametric oscillator for the generation of tunable 1.5–1.6 μm radiation in the mW power range. The spectrum analyzer and synthesizer are to be used for evaluating the beat-note and phase noise characteristics of optical parametric oscillators and optical frequency comb generators.

2 Research Summary

Under AFOSR DURIP-95 Grant F49620-95-I-0505 "Diode-Pumped Optical Parametric Oscillator and Optical Frequency Comb Generation at 1.5 μm," we have purchased or fabricated the requested equipment items and initiated two research projects that cannot be pursued without the new instruments. In this final report we shall summarize how the new equipment items are to be used in supporting current research and enabling our new investigations.

2.1 Equipment Purchase

Under the instrumentation grant, we purchased three equipment items. The first item is a high-stability, 2-GHz rf synthesizer: HP8643A with options 001 and 002. The second item is a low-noise, 26.5-GHz microwave spectrum analyzer: HP8563E. The third item is a fabricated equipment for a diode laser-amplifier. The diode laser system is based on a design by Dr. Leo Hollberg of the National Institute of Standards and Technology (NIST) at Boulder, Colorado. It consists of a master laser at a center frequency of 790 nm that is used to injection lock a SDL 500-mW diode laser amplifier. The diode system yields a high-power tunable laser source centered at 790 nm. Some of the parts and especially the laser scanning and servo control electronics were purchased from NIST. Phillip Nee, a graduate student, went to NIST to assemble and set up the diode laser system.

2.2 Benefits to Current Research

The rf spectrum analyzer and synthesizer has been used to improve our measurement capability in optical frequency comb (OFC) generation [1] and in phase locking of a optical parametric oscillator (OPO) [2, 3, 4]. In OFC generation, the 26-GHz spec-

trum analyzer is used for monitoring the coupling efficiency of the resonant electro-optic modulator at the modulation frequency of 17 GHz. In addition, the spectrum analyzer makes it possible to detect the beat frequencies between an unknown optical frequency and a sideband of the OFC. The 2-GHz rf synthesizer is used to fill an important gap in our rf source capability that now extends to 26 GHz. It will be used for demodulation of beat notes between the signal and idler outputs of a phase-locked OPO and also in the beat measurements using an OFC. Both the OPO and OFC generation projects are related to ultrahigh precision frequency measurements for use in areas such optical frequency counting and synthesis [5, 6], and optical frequency referencing for dense optical communication networks.

The tunable diode laser-amplifier has been utilized to generate tunable 1.6 μm light by use of difference-frequency mixing in a periodically-poled lithium niobate (PPLN) wafer [7] that is quasi-phase matched for inputs at 790 nm and 1.55 μm. It is currently used in a double difference-frequency mixing experiment for demonstrating an exact 3:1 frequency ratio [8]. The first stage involves the mixing of the diode laser at 798 nm and the second harmonic of a diode-pumped YAG laser at 532 nm in a cesium titanyl arsenate (CTA) crystal to generate an output at 1596 nm [9]. The second stage uses the 798 nm laser and the 1596 nm output from the first stage in a PPLN wafer to generate another 1596 nm output. The two 1596-nm outputs will then be detected using a high speed photodetector to measure their beat note. By tuning the 798 nm diode laser to set the beat note to zero, an exact 3:1 frequency ratio between the two input lasers can be obtained. These experiments are related to optical frequency counting and synthesis and the generation of compact tunable 1.5–1.6 μm source.

2.3 Benefits to Future Research

The new equipment makes possible some new research in nonlinear optics and optical information processing. The diode laser will be used to pump a PPLN-based OPO with cw outputs at 1.5–1.6 μm in the mW range. This diode-pumped OPO source will be useful as a compact tunable source in fiberoptic communications and in high precision measurements. Another important research area is the investigation of a diode-pumped optical parametric amplifier (OPA) for use as an optical frequency shifter in dense wavelength division multiplexed (WDM) communication networks and in multi- wavelength information processing. This OPA-based frequency shifter should have a large bandwidth of $\sim$15 THz and high conversion efficiency.

The tunable OPO source will also be used as an input to an OFC at 1.5 μm for the generation of multi-terahertz-span frequency markers. The rf synthesizer and spectrum analyzer will be used for measuring the characteristic of the OFC output.

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